

BACHELOR OF SCIENCE (B.Sc.)

Term-End Examination

01702

June, 2017

PHYSICS

PHE-11 : MODERN PHYSICS

Time : 2 hours

Maximum Marks : 50

Note : Attempt all questions. The marks for each question are indicated against it. The values of physical constants are given at the end. Symbols have their usual meanings.

1. Answer any *five* parts :

5×3=15

- (a) The average lifetime of a π -meson at rest is 26 ns. The meson is moving with a speed of $0.9c$ with respect to the Earth. Calculate its lifetime as measured by an observer at rest on the Earth.
- (b) Show that in the limit $v \ll c$, the expression for the relativistic kinetic energy approaches the classical kinetic energy.

- (c) Write down the probabilistic interpretation of the wave function.
- (d) The lifetime of an excited state is 8 ns. If this is the uncertainty in photon emission, calculate the uncertainty in the frequency ($\Delta\nu$).
- (e) Draw approximate energy levels for the L and K shells and show all the allowed transitions.
- (f) State whether or not the following reactions are allowed :
- (i) $n \rightarrow p + e + \bar{\nu}_e$
- (ii) $\bar{\lambda}_0 \rightarrow p + \pi^-$
- (g) List three applications of radioisotopes as tracers.
- (h) The mean life of a radioactive element is 14 months. Calculate the time required for 75% of the element to decay.

2. Answer any *one* part :

$1 \times 10 = 10$

- (a) (i) A particle moves with a uniform velocity \vec{v} relative to the S-frame. Derive an expression for its velocity relative to a frame S' which is moving with a uniform velocity $V\hat{i}$ relative to the S-frame.

- (ii) A person on the moon observes two spaceships moving towards him from opposite directions at speeds of $0.7c$ and $0.8c$, respectively. Calculate the relative speed of the two spaceships as measured by an observer on either one. **6+4**
- (b) (i) Using the expression for the relativistic linear momentum of a particle and the mass-energy equivalence, derive an expression relating the energy and momentum of a relativistic free particle.
- (ii) Calculate the potential difference through which a proton must be accelerated to achieve a speed of $0.6c$. (Rest mass of the proton is 938 MeV) **6+4**
- 3. Answer any *two* parts : $2 \times 5 = 10$**
- (a) In a region of space, a particle with mass m and zero energy has a time independent wave function :
- $$\Psi(x) = A x e^{-x^2/L^2}$$
- where A and L are constants. Use the Schrödinger equation to determine the potential energy of the particle.

- (b) A photon and an electron each have an energy of 6.0×10^3 eV. Calculate their respective wavelengths. Which of these could be used to probe atomic structures? Explain.
- (c) Prove the Ehrenfest theorem for the position operator :

$$\frac{d \langle x \rangle}{dt} = \frac{1}{m} \langle p_x \rangle$$

4. Answer any **one** part :

$1 \times 10 = 10$

- (a) Write down the Schrödinger equation for a one-dimensional harmonic oscillator with an angular frequency ω . Calculate the mean potential energy of a simple harmonic oscillator in its ground state :

$$\Psi_0(x) = \left(\frac{a}{\sqrt{\pi}} \right)^{1/2} \exp\left(-\frac{a^2 x^2}{2} \right)$$

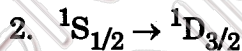
$$\text{where } a^2 = \frac{m\omega}{\hbar}.$$

What is the energy eigenvalue of the ground state? Is the ground state of even parity or odd parity?

$2+6+1+1$

(b) (i) Write down the time independent Schrödinger equation for the hydrogen atom. Explain the significance of the three quantum numbers in the eigenfunctions of the hydrogen atom. 2+3

(ii) State with reasons whether the following transitions for a multi-electron atom are allowed or not : 5



5. Answer any *one* part : 1×5=5

(a) Sketch the binding energy/nucleon as a function of the mass number. How can it be used to explain the fission and fusion phenomena ? 3+2

(b) With the help of a diagram, explain the working of a cyclotron. 5

Physical Constants :

$$h = 6.62 \times 10^{-34} \text{ Js}$$

$$m_e = 9.1 \times 10^{-31} \text{ kg}$$

$$c = 3 \times 10^8 \text{ ms}^{-1}$$

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